KTH Optimization and Systems Theory

Optimization and Systems Theory Seminar
Friday, April 27, 2001, 11.00-12.00, Room 3721, Lindstedtsvägen 25

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Schooling autonomous vehicles with artificial potentials

We describe distributed control laws that are designed to allow a group of autonomous vehicles to perform maneuvers that resemble schooling or flocking. Natural schools and flocks are notable for their remarkable capacity to display highly organized group-level behaviors; the group exhibits an "emergent intelligence" that arises from individual-level behaviors. For our group of vehicles, we govern individual-level behavior with control laws that derive from artificial potentials. Artificial potentials define local interaction between neighboring vehicles so as to enforce desired inter-vehicle spacing and inter-vehicle orientation alignment in the emergent schooling behavior. Virtual beacons are introduced to manipulate group geometry and direct the motion of the group. A virtual beacon is a moving reference point that influences vehicles in its neighborhood by means of additional artificial potentials. A Lyapunov function is constructed from the artificial potentials for analysis of the closed-loop, multiple-vehicle system dynamics. In the case of orientation control of multiple rigid underwater vehicles in 3D, we make extensive use of symmetry, reduction and other tools from geometric mechanics. We conclude with a discussion of the multiple underwater vehicle experimental test-bed that we are developing at Princeton.

Calendar of seminars

Last update: March 21, 2001 by Anders Forsgren, anders.forsgren@math.kth.se.

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Scope for application of GPS in Indian coal industry

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Introduction

Before we get onto the core issue , let us try to recap as to when and where GPS started. The first one called NAVSTAR GPS (Navigation Satellite Timing and Ranging Global Positioning System) was (and still is) a satellite-based radio navigation and surveying system providing precise three dimensional position, navigation and time information to suitably equipped users everywhere on a continuous basis.

The system consists of 24 satellites including three active spares , placed in near circular orbits in six orbital planes of 55 o inclination at height of about 20,200 km. There are often more than 24 operational satellites as new ones are launched to replace older satellites. The orbit altitude is such that the satellites repeat the same track and configuration over any point approximately every 24 hours. The satellites have 12-hour periods so that atleast 4 satellites are available for observations for positioning on ground, sea and air at any time throughout the year anywhere in the world. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Signals from four satellites are required to compute the four dimensions of X, Y, Z (position) and Time at any point on Earth.

GPS was developed and funded by the U. S. Department of Defence (DOD) during early 1970s primarily for military applications with limited access to civilian users. Virtually all of the development of GPS equipment was under contract from the DOD (US). Many of the contractors to the government also had commercial involvement in similar technologies, especially receivers. This meant that by the early eighties, commercial interest in GPS began to

blossom. By 1990, although the system was not fully implemented, it was sufficiently reliable to make general commercial and even personal use viable. The system has now been completed and is in full commercial use

GPS Applications GPS receivers have been developed which observe signals transmitted by the satellites and achieve upto 2cm accuracy horizontally and 3cm vertically anywhere on earth's surface. They have the following advantages over conventional methods of navigation or surveying:

- Inter-visibility between points is not required.
- All-weather operation.
- Day and Night operation.
- Distances upto thousands of kilometers can be measured.
- Fast and economical method.

GPS receivers are used for navigation, positioning, time dissemination, and other research. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals.Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples. Monitoring of ground movements by repeated or continuous measurements can be done.GPS can be economically employed for all types of survey mapping and tracking work in conjunction with other uses.It is a powerful means to support Land Information System (LIS) and Geographical Information System (GIS).

Time and frequency dissemination, based on the precise clocks on board the satellites and controlled by the monitor stations, is another use for GPS. Astronomical observatories, telecommunications facilities, and laboratory standards can be set to precise time signals or controlled to accurate frequencies by special purpose GPS receivers. Research projects have used GPS signals to measure atmospheric parameters.Now, there is an increasing confidence in adapting GPS to other commercial and social applications.

GPS Accuracy
GPS achieves integrity and protects users against system anomalies and failures by relying on satellite self-checks and , as well as signal assessment by users. Thus, GPS has both integral and independent mechanisms to assure integrity.Augmented GPS systems have additional built-in integrity monitoring that can benefit GPS users. Differential GPS (DGPS) and Real time Kinematic (RTK) systems, such as the network operated by the U.S. Coast Guard (USCG), use an onsite integrity monitor to check satellite-signal validity and provide an independent assessment of satellite health. Because of the real-time capability, continuous availability and the high accuracy potential, GPS usage is very broad and is still growing.

GPS reliability
Since GPS user equipment does not transmit, there is no limit to the number of GPS receivers that can be used on the system. There are no licensing fees for the receivers and no requirement to register their ownership. There are no restrictions on the use of GPS for positioning and the received data/information can be stored and re-transmitted, if required.

Background on Coal Industry
Coal is the primary source of power generation in many countries of the world, and is the most abundant, widely distributed, safe and economical fossil fuel available to meet the escalating energy demand, providing around 33% of global primary energy needs and generating 36% of world's electricity at present. Coal continues to be the pre-dominant energy source in

India contributing to about 63% of its total energy needs.

Coal mining in India commenced in 1774 and has come a long way from a production level of 6.19 Mt. in 1900 to about 310 Mt. in 2000-01. Coal production increased rapidly after nationalisation of coking coal mines in 1972 and non-coking coal mines in 1973 undertaken to ensure coal conservation and scientific development of coal resources in the country. Public sector coal companies contribute 98% of India's coal production, of which Coal India Limited accounts for 88% and Singareni Collieries Company Limited(SCCL) for 10%. Other companies like DVC, IISCO, TISCO and captive mining firms make up the balance.

Predominance of surface mining in the Indian coal industry with a share of over 80% and 54% respectively of total production in Coal India Limited and SCCL, calls for insightful analysis of the means and methods for upgrading the production and performance of surface mining systems in the 21st century. Even if there are surface mining systems of variegated sizes and sophistication, there is no doubt whatsoever that surface mining systems from small scale to medium scale and mega-sized mines, would call for significant inputs of new technology to be cost effective, environmentally friendly and meet the production requirements. In striving for new levels of performance in the competitive environment of the 21st century, technology will be the principal lever for change, where information technology (IT) will play a key role.

Benchmarking of surface mining operations world-wide reveal a yawning gap between the performance capability of the best of the mines and the worst of the mines and there exists an imperative need to bridge this gap. Since, the scale of operations in opencast coal mines in India has grown by leaps and bounds, the conventional methods of surveying, planning and operating the mines would have to be upgraded to meet the requirements. A whole host of leading edge technology products and systems for effective management of surface mines have evolved in the past decade.

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Scope for application of GPS in Indian coal industry

GPS Applications in Coal Industry

GPS entered the Mining Industry as a fast, and cost-effective instrument for survey. A shifting landscape is the very nature of mining operations; as shovels and dozers remove coal and ore, they reshape the mine's surface. Real-time GPS allows mining operations to keep on top of these constant changes and provide updated operating instructions to heavy equipment operators. In addition, GPS systems provide a fast and accurate solution for replacing and maintaining control points and calculating the volume of material moved.

Moving mining assets, including dozers, shovels, graders and draglines, are managed and guided using advanced GPS technology. Advanced GPS systems also track and monitor the status and location of dump trucks, providing reports to their heading and velocity as well as the size of the truck's load. Live GPS is becoming commonplace for monitoring and dispatching haul trucks or drills and for providing grade control on shovels. These data can also be tied to a GIS to monitor the location of all equipment, in real time.

GPS being an all-weather real time, continuously available, economic and very precise positioning technique , would have wide range of applications in Indian coal industry. The potential areas for usage of GPS in Indian coal industry includes –

Surveying

Several modern surveying techniques like Satellite Remote Sensing, Photogrammetric, Field surveying procedures using digital theodolites, short and long range EDM instruments like Total Station etc., are available today. However, the advantages of using the satellite based GPS techniques for surveying are:

- GPS measurements do not require inter-visibility between points whereas the conventional surveying tools require line of sight for measurements.
- GPS technique provides a three dimensional position for the point. That is in one go, we get the horizontal and vertical position of the point, unlike in conventional surveying where we need two operations viz., horizontal traverse for planimetric control and a level loop for

height control.
- A very high accuracy measurement can be made in a relatively short time for baseline lengths of a few hundred meters to few hundred kilometers and can provide the same accuracy anywhere on earth, in almost any weather condition and at any time of the day.

GPS offers many advantages compared with conventional survey methods. Because there is no need for a rod person, each surveyor can work alone when necessary. GPS also requires much less setup time than did traditional surveying equipment, so the crew can use its time more efficiently. It can also keep a much more flexible schedule and move from one area to the next or one pit to another as needed.

Opencast Mine Operations
The entire opencast mine earthmoving process can be monitored and enhanced by GPS equipped heavy earth mining machinery (HEMM). Computerized mine operations management system would include tracking of mining equipment, maintenance, monitoring and diagnostic systems, transmission of loading instructions to dumpers etc for better control.

The System Network
Basically the requirement comprises of mounting the GPS instrument within the HEMM/equipment operator's cabin with an antenna alongside to facilitate receipt of satellite signals. GPS is integrated with the Graphical Operator Interface Console which in turn has a receiver (infra-red) attached on the sides of the equipment that enables relay of information to the central computer located in the control/mine manager's office at a distant place from the mine. Using a multidirectional radio, each vehicle's onboard computer sends GPS-based position information back to a dispatch computer, which corrects the data.

This computer monitors the location and status (full or empty, heading, and velocity) of each vehicle in the fleet. The system analyzes production statistics, such as haul routes, historic data about drive time to a specific shovel location, and cycle time — how long it takes to make a round trip from the shovel to the dump site and back. The system then correlates these data to most efficiently route all the vehicles.

By having real-time access to each vehicle's position, the dispatch system can determine if several trucks are waiting at one shovel and, if so, route them to a different shovel. This helps prevent bottlenecks and keeps operations moving freely. The dispatch computer can also determine the most efficient location for the truck to dump its load at any given time. Essential Features of truck monitoring system -

- Satellite reciever
- Radio repeater tower (ground reference station)
- Central control room
- Truck / drill HEMM based antenna
- Radio base station

Operator's Feedback and System Response
After the truck operator unloads as assigned, the dispatch computer can give the driver his or her next assignment — determining at which pit the truck is needed and whether the operator will haul overburden or coal, depending on the mine's needs. At the administration building, human dispatchers can view on their 21- inch computer screens the data from any DGPS-fitted support equipment. For example, if mine personnel should need a motor grader or water truck sent to their area, a dispatcher could identify the nearest appropriate machine and dispatch it to the area by way of a voice radio,

further optimizing truck use.

Optimization Models

- Mine topography
- Road network
- Pit configuration
- Truck availability
- Coal blending / bands excavation schedules
- Dumping grounds distances
- Real time travel times
- Spare part mgmt
- HEMM downtime mgmt
- Reassignment evaluation of HEMM

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Maintenance Downtime controls

The dispatch computer also stores vehicle maintenance records. In-vehicle engine-and transmission-monitoring devices continually report any out-of-range readings, such as high oil temperature. The system notifies the dispatch operator of the problem when it occurs, storing the time-stamped information in the database. Office or maintenance personnel can poll the trucks or shovels at any time to determine current operational status.

"Proximity decision" too could be achieved with the GPS data. In this technique, "virtual beacons" are created for key mine locations, benches, dumps, crushers, workshops, haul road intersections etc. Virtual beacons is a database entry that contains the "X" and "Y" coordinates of a location and let the system know when the equipment enters or leaves the location area. Network data of virtual beacons is stored in local memory on-board the mobile equipment. During the course of movement, GPS receivers continually change the positional data and whenever the equipment enters or leaves the "virtual beacon" (circle of influence), on board communication processor notifies the central computer, which then uses the data in its equipment assignment decisions.

Maintenance management

- Work order administration
- Service schedules
- Maintenance reporting
- Major component tracking
- Repair & defect analysis
- Allocation of resources
- Priority setting

Benefits from the system

- Higher productivity
- Better turnaround of HEMM
- Optimum spare part management
- Operator performance guide

- Production scheduling
- Pit development recomputations
- Optimal traffic flows in the pits
- Hot seat exchange and shift change mgmt

GPS in US coal mines .... & india

Caterpillar Company had developed prototype Computer Aided Earthmoving System (CAES) including on-board display of the excavator/shovel and also the mine operational bench in the geological plan of the mine area. Real Time Kinematic-GPS (RTK_GPS) aided positional data is dynamically displayed on the mine plan and thus aids in locating the shovel on the selected bench, upto centimeter accuracy. Advanced versions even show the plan view in colour and indicate the volume/quantity that has to be removed or filled. Display of the profile too is enabled alongside on-board computer. As the machine works, terrain updates, using GPS technology, are collected and transmitted back to the office, where the entire data is monitored. Operations of a number of such equipment can be monitored at the office. Immediate production calculations are facilitated at the office as well as the conventionally developed computerised mine plan updated simultaneously.

Location of drilling machines can be precisely done with the RTK-GPS that are mounted together with the on-board graphic console for drill operator's guidance. The console displays "virtual" drilling pattern, using pre-determined blast hole coordinates in the systems database. The computerised mine plan in the on-board system also aids in displaying the vertical profile of the geology of the area and thus indicate the drill hole advancement/intersection of the sub-surface stratum as the drilling progresses.

DGPS machine control in opencast mines would enable improvement in mine productivity and efficiency. High precision GPS systems can support an unlimited fleet of mine equipment and by monitoring the entire fleet from an office centrally located, better control can be established and even decisions transmitted to the on-board graphic consoles. Certain modules on equipment maintenance/condition monitoring too could be simultaneously stored in equipment system for productivity versus expected real time consumption for the mining task attached to that equipment; thus assisting in the day-to-day mine production planning.

India's coal production is expected to double at 600 million tonnes in the next decade and to realise this impressive growth, optimum utilisation of modern technologies like geographic information services (GIS) and global positioning systems (GPS) in all facets of mineral exploration are essential. The government is urging the industry to make efforts for increasing use of GPS technology for locating new mineral resources and improved scientific planning for exploitation of natural resources and better management systems. GPS is being used extensively inbench height control, drill elevations, topographic surveys and geological mapping in Indian coal mines.

GPS based Truck Despatching Systems, have been introduced recently at Gevra Opencast Project (SECL) , West Bokaro Collieries (TISCO) ,and Northern Coalfields . Based on their performance, the same is being replicated in other big opencast coal mines in India notwithstanding the fact that it is a capital intensive project . What perhaps needs to be encouraged is that the spirit behind the use of GPS applications must be viewed as beneficial to the coal company and in turn , to the coal miners themselves.

Conclusions

GPS is a powerful surveying tool, which can provide on its own or in combination with other ground survey technique the required speed, accuracy and economy in surveying of large mining or opencast blocks.

However, the GPS based real-time optimization of HEMM deployment in opencast mines typically works well within a strict set of conditions. Production interruptions can have a significant impact on overall performance. In a coal mine, these interruptions include shift changes, scheduled and unscheduled maintenance, events like shovel breakdowns or servicing, lunch breaks, and numerous other routine events that are all part of a typical shift. An added complication is variability in data integrity. The loss of a truck's GPS or radio antenna can make it invisible to the system, creating a situation where assignments for other trucks are made without considering the location and status of the non-reporting truck.

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Objective

GIS Development strives to promote and propagate the usage of geospatial technologies in various areas of development for the community at large. It remains dedicated to foster the growing network of those interested in geo-informatics worldwide and Asia in particular. Through its activities, it assists community and government in developing their capabilities, and policies and facilitate knowledge transfer to grassroots and strengthen the productivity and management capabilities.

It encourages the exchange of scientific know-how through its three key platforms. It brings out an internationally acclaimed monthly science magazine publication GIS@development, which is in its 8th year of global circulation. It holds the world's largest geospatial technical resource portal www.GISdevelopment.net. It organizes the annual international conferences and exhibitions of Map Asia (www.mapasia.org) and Map India (www.mapindia.org).

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3. Conferences and Exhibition – Map India and Map Asia

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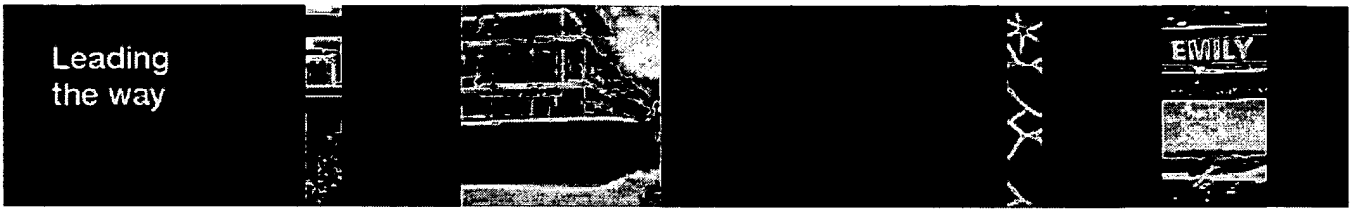


Diagnosis Simon Ryder

"Four elegant probes, their smooth, shiny forms reminiscent of medical instruments, are sited one outside each of the main entrances to the new hospital. They reach into the sky, sensing the world around, taking the pulse of Gloucestershire: the up-to-the-minute measurements they display ~ one air temperature, one pressure, another humidity and the fourth air flow (wind speed and direction) ~ the basis for a diagnosis."

temperature ~ warmth
pressure ~ pulse
wind ~ breath
humidity ~ moisture

Diagnosis
Outpatients light sculptu
GRASP
Link corridor panorama
Bedside cabinets
Galleries
Vinyl flooring
Children's welcome wall
Outpatients welcome wa
Outdoor flooring
Bubble tower/lift
Wall work to theatres
Treatment Rooms

These four weather masts, each topped by a single word – warmth, pulse, breath, moisture – link inside (the body) with outside (the environment). A visible expression of the hospital's role. A wider view of health. A public tool for diagnosis. A fifth, virtual mast – the web mast – bringing all the weather information together, broadcasting it to anyone in Gloucestershire with access to the internet, also to every bedhead internet terminal in the new hospital.

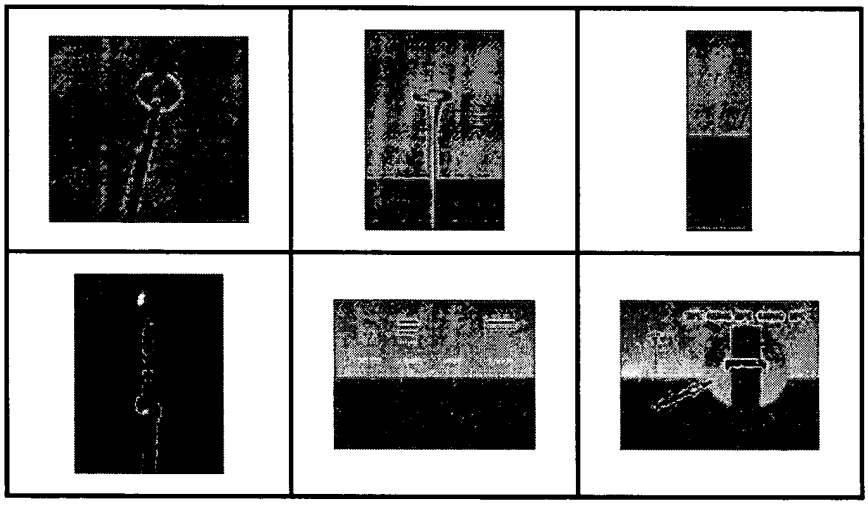
The beacons are not only diagnostics (displaying their precise readings via ground-level LED displays), but also wayfinders, helping visitors to orientate around the hospital site. Differently coloured bands of pulsating neon make each beacon highly distinctive, the coloured light responding to that beacons weather data while also making it highly visible, day and night.

The design of the masts
The masts are intended to blend with the modern style and materials used in the new building, as well as with the function of the hospital: a

medical instrument on an architectural scale. They will be made out of steel, with a hollow glass tube on top within which will be a word (warmth, pulse, breath and moisture), one per mast. This top element will be highly visible and reflective from some angles, but then in other lighting conditions it will become almost invisible, dissolving into the atmosphere that the mast is measuring.

At ground level, an LED display will give an accurate reading, updated each minute, of that beacons weather data: the warmth mast will give a reading of temperature (°C and °F), the pulse mast pressure in millibars, the breath mast air flow in mph and points of the compass, and the moisture mast relative humidity in percent. After each reading a word will follow, again relating the date to the body: rising, stable, falling.
High up on each mast there is a band of pulsating coloured neon, the colour and form of which reflecting the element of the weather each mast is representing. The warmth mast will have orange/red neon, in a vertical scale, responding to the temperature; the breath mast will have a horizontal circle of purple neon, divided into segments to show which direction the wind is coming from; the pulse mast will have concentric circles of green neon, taking it inspiration from the isobars on weather maps (the closer together they are, the greater the change in pressure); the moisture mast will have a blue 'bowl' of neon, filling up as the humidity rises.

East mast's neon will gently pulse (give a clear visual message for wayfinding), and as the pulse of light fades away part of the neon will remain on in response to the weather (the more left on the greater, for example, the temperature): pulse, fade, reading revealed, pulse, fade.....
The colour and form of the neon is also open to being represented as simple graphics, which could be used on letterheads or other hospital stationary or wayfinding, to help guide visitors to the right entrance on their first visit to the new Gloucestershire Royal.



How it works
Weather: a central, solar-powered weather station will be situated on the roof of the hospital. This will measure four aspects of the weather: temperature, pressure, humidity and wind (speed/direction). Outside each of the main entrances to the hospital there will be a 'weather mast', each one responding to a different aspect of the weather. Information from the central weather station will be transmitted via radio (operating at 2.4GHz, a regulated public frequency) to the beacons, which will

display the current weather reading: one beacon will display termperature, one pressure....and so on. This weather information will be updated every minute, 24-hours a day.

There will also be a fifth, virtual beacon. The central weather station will transmit the weather data to the internet, via a PC on the hospital's computer network. A page on the Leading the Way website will display this information, again automatically updated every minute of the day. It will also display historical data, such as the change in pressure over the previous month. This will make the beacons and the information that they display not only available to anyone with an internet connection within the county of Gloucestershire, but also to individual beds in the new hospital which through the Patient Power scheme will all have bedhead internet access. It will also be open to being used as a valuable resource for local schools.

Light: the beacons are also required to aim wayfinding around the site. They are therefore tall (and in proportion to the new building), highly distinctive in structure (that echoes materials shapes found in the new architecture and within the hospital), and will have a ring of neon around the top. The colours of the neon have been chosen to be distinctive from all the other lighting and lit signage around the site, rather than to compete with it. The beacons are intended to be a gently pulsating presence, with subtle colours that are not found anywhere else in the vicinity.